

## Binary decomposition-based image cipher algorithm with flexible method for key construction

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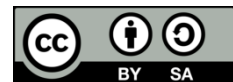
Secret keys

Smart key constructions

### ABSTRACT

Image security is still one of the important fields in multimedia processing because it's used in our daily lives. Watermarking, steganography, and ciphering are three directions to keep an image secret. Encryption defined as the process of changing information (which called plaintext) into an unreadable secret format (which called cipher-text). A new ciphering algorithm based on binary decomposition and binary codes conversion is proposed in this paper. The key is constructed in a flexible way based on the size of a secret image using some logical operations to increase the security levels. Three test images in different sizes were used to evaluate the performance of the proposed algorithm. The results of the visual scene and statistical factors proved that the suggested method was ciphering the image with high security. The proposed work was validated to confirm its effectiveness. As conclusions, the uses of decomposition and simple binary operations have given high-level image security. Also, key construction is an important step to face several types of attackers.

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## 1. INTRODUCTION

Multi-media fast developing in last years required improving the processing techniques for video, audio and image files. Digital image was one of the interest fields in the multi-media word that need to enhance its tools and techniques in the several directions such as enhancement, recognition, security, comparison, segmentation, etc. Today, keeping images secure become one of the complicated challenges that facing security technicians in transferring and storing images operations [1]-[5].

Image encryption techniques play a important role in multimedia applications to secure and authenticate digital images. In general, the multimedia security techniques are classified into encryption and hiding. Encryption techniques effectively protect multimedia information by converting it into an unknown form by the adversary [6]. Since the 16th century, encryption techniques appeared and remained constantly evolving in parallel line with hacking techniques improving. Image encryption techniques classified depends several vactors to multiple techniques for example: based on representation to frequency or spatial domain, based on key to private or public key, the data size that encrypted at a time to block or stream [7]-[10]. Encryption in the spatial domain is more effective than frequency domain in terms of simplicity and computational cost, consequently encryption in the spatial domain is more compatible with image encryption.

The values or locations or values and locations pixels in digital image will be changed in ciphering techniques that based on spatial domain [9]. Recently, much ciphering algorithms based on chaos theory were proposed for image encryption [11]-[16]. However, the computation more complicated and the security levels are low in chaos theory based ciphering algorithms [17]. Other ciphering algorithms were proposed based on decomposition techniques [15], [18]-[21]. However, the drawbacks of those techniques were the security levels rustiness because of the bit planes numbers and its contents are constant in additive to key space were little. Advanced encryption standard (AES) and data encryption standard (DES) are famous ciphering algorithms called naïve encryption algorithm which used in many applications such as smart cards, cell phone, automated teller machines, and internet servers [22]-[23]. Main problems in the naïve algorithm were computation cost so much and have artifacts appearance in the ciphered image when the original has a large region of a single colour [24]-[25].

In this paper, binary codes decomposition-based image ciphering algorithm was proposed. Binary codes were used to decompose the image before reordering the bit planes. Image confusion was achieved using ASCII codes and add round key. New method was used to extraction key from secret image itself. The paper sections will be explained in Section 2 the details of proposed image ciphering algorithm for encryption and decryption will be shown. The results will be showed in Section 3. The paper conclusions explained in Section 4.

## 2. METHOD

The proposed method for encryption and decryption will be described in details as the following steps. Part A explain the steps of encryption, while the decryption steps explained in part B. After that, part C shows the steps of key construction. Finally, the block diagrams of encryption, decryption and key construction steps are shown in Figures 1 and 2.

A. Encryption part: the steps of the proposed encryption algorithm are explained below.

1. After reading the secret image, it will be decomposed using binary bit planes to get 8-planes with ones and zeros values then these bit planes reordered before reconstruction secret images from reordered bit planes.
2. Convert the pixels values of the reconstructed image from decimal to hex-decimal, where the value of each pixel is represented in two digits in the hex-decimal system.
3. Each digit of the hex-decimal pixel value is converted to its equivalent in ASCII codes which are represented in two digits.
4. Add round key is the final step where XOR logical operation between key results from key expansion operation (will be explained in subsection c) and pixel values results from ASCII operation.

B. Decryption part: it is reverse of encryption steps as shown below:

1. Add round key operation through EX-OR logical operation between secret pixel and key
2. Convert the resulted image from AddRoundKey operation Hex-decimal system
3. The Hex-decimal number converted to its equivalent in decimal.
4. Decomposing the image to binary bit planes before re-ordering its to initial order, then reconstructing the image from reordered bit-plane to get the secret image.

C. The key construction operation: the steps for the key construction according to the size of the desired image are demonstrated as follows:

1. Choose four pixels from the same image that needs to encrypt.
2. Create a logical AND operation between two of them and a logical OR operation between the other two, and then perform a logical XOR between the outcome of the two processes, as demonstrated below.
 

```
Pixel_1=image (150,25)
Pixel_2= image (15,150)
Pixel_3= image (100,105)
Pixel_4= image (115,10)
Outcome_1=bitand (Pixel_1, Pixel_2)
Outcome_2= bitor (Pixel_3, Pixel_4)
Outcome =bitxor (Outcome_1, Outcome_2)
```
3. Derive an entire key according to the size of the image based on the outcome of the previous logical operation, as explained below.
  - Decrease the value of the outcome logical operation by one and if the value reaches zero, then complemented it to become 255.
  - Create a matrix that contains all values of the entire key.

4. Perform a logical XOR operation between the derived key and the required image that needs to encrypt.
5. Return the values of four pixels to the cipher image in order to utilize them in the receiving part for reconstructing the original image.

Figure 1 illustrates the block diagram of the key construction steps. Figures 2 demonstrate the different stages used for the proposed scheme at the sending and the receiving sides, which mean encryption steps in Figure 2(a) and decryption steps in Figure 2(b).

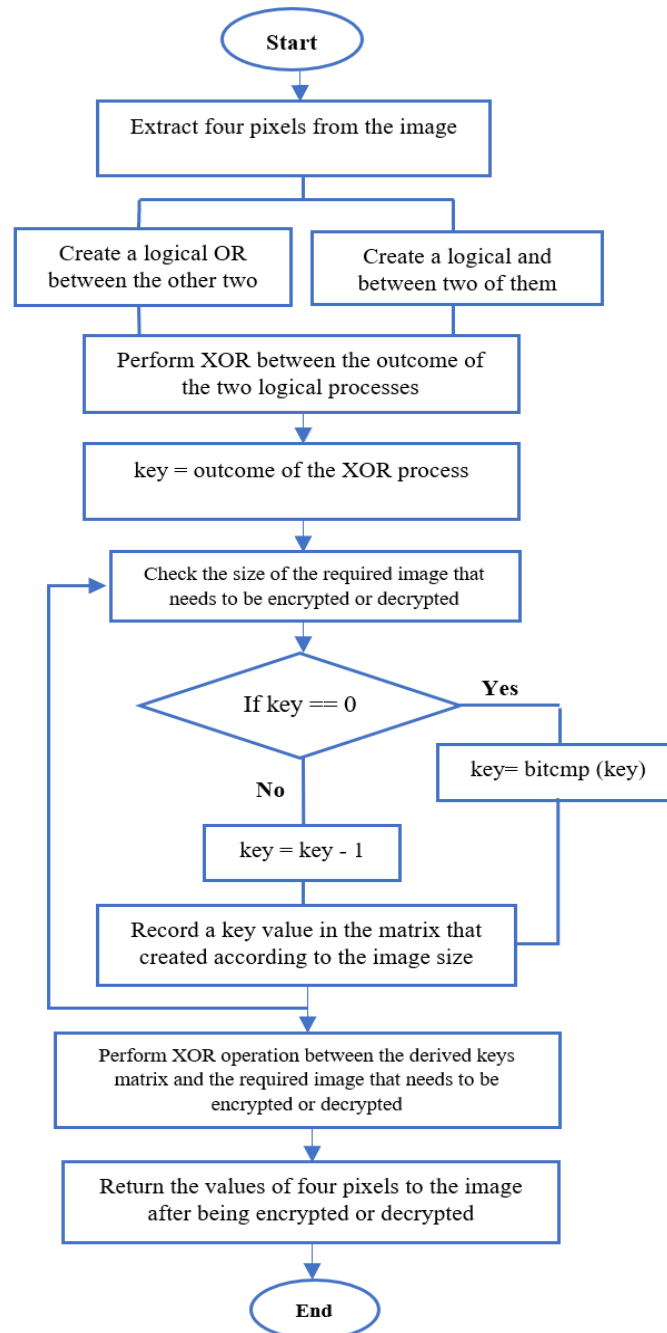


Figure 1. The key construction process

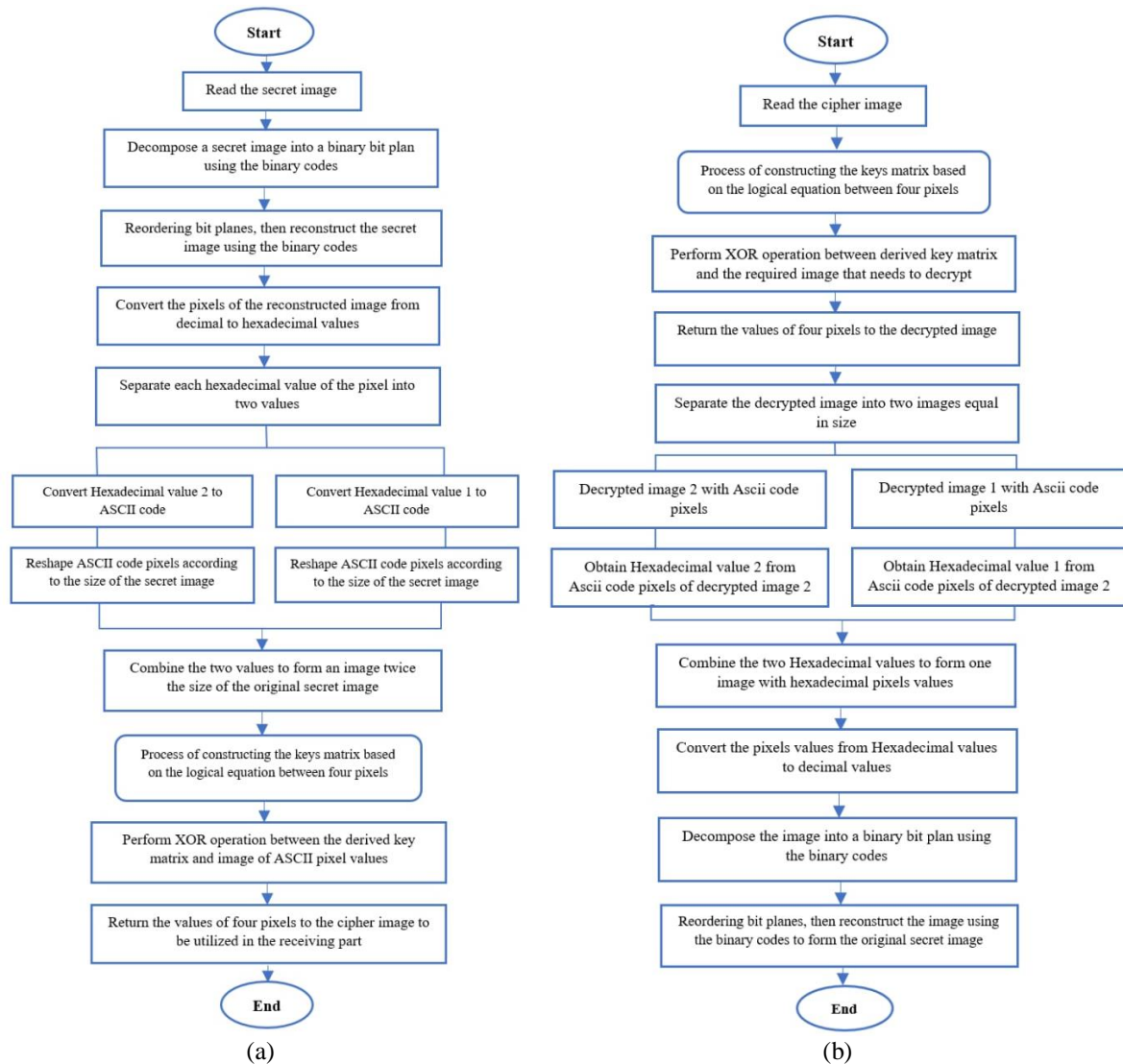


Figure 2. Proposed ciphering algorithm (a) the sending side and (b) the receiving side

### 3. RESULTS AND DISCUSSION

MATLAB (R2020a) is utilized for the implementation of the proposed algorithm. Images of different sizes (256×256, 512×512 and 1024×1024) are tested to observe the performance of the proposed scheme at sending and receiving sides, respectively. All images utilized for the test are taken from the image database ("SIPi Image Database"). The suggested algorithm performance was evaluated through visual scenes of image after each step with its histogram (see Figures 3-5) in additive to statistical evaluation as shown in Table 1. Figures 3(a)-(d), Figures 4(a)-(d), and Figure 5(a)-(d) depict the images with their histogram through the different stages used for the encryption scheme at the sending side.

As depicted according to the figures above, ciphered image visual scenes of all tested images are compatible with ciphering requirements. The histogram of the encrypted image is different from the histogram of the original image, it is close to the uniform distribution and that indicates the strength of the suggested encryption algorithm performance. On the other hand, the other important point is the encrypted image is quite different from the original image in terms of size, which increases the security levels through camouflaging the attacker about the original image size. However, this increases the transmitting channel requirements.

Table 1 explains the entropy values for the tested images and the time spent for the images tested at the sending and receiving sides, respectively. Relative to the values shown in Table 1, the efficiency of the proposed algorithm can be observed in terms of the little time spent at the sending and receiving sides, respectively. In addition to entropy values that are close to 8 for the images utilized to examine the

performance of the suggested algorithm. To confirm the effectiveness of proposed algorithm was validated with work in [26] through comparison the ciphered image entropy and algorithms execution time as shown in Tables 2 and 3.

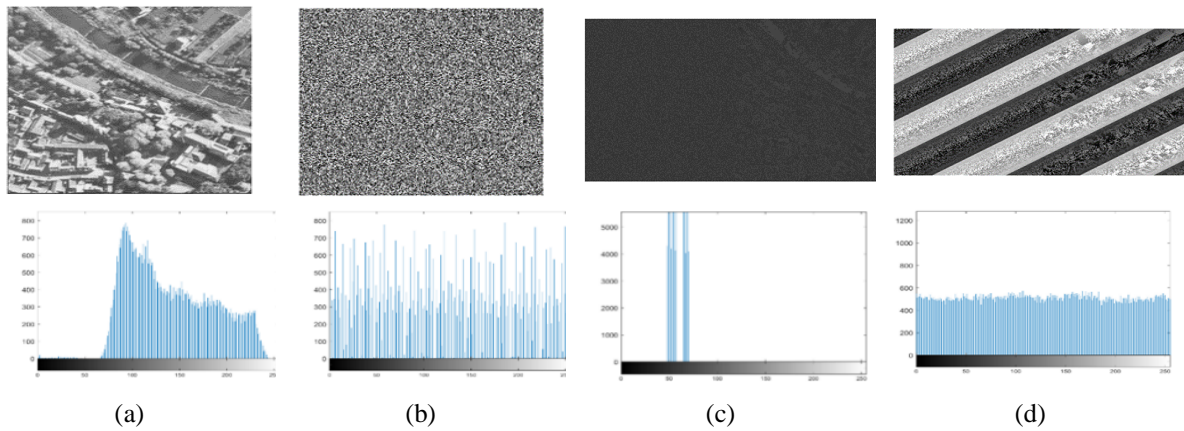


Figure 3. 256×256 Aerial image (a) secret image, (b) decomposed image, (c) converted to ASCII code, and (d) ciphered image

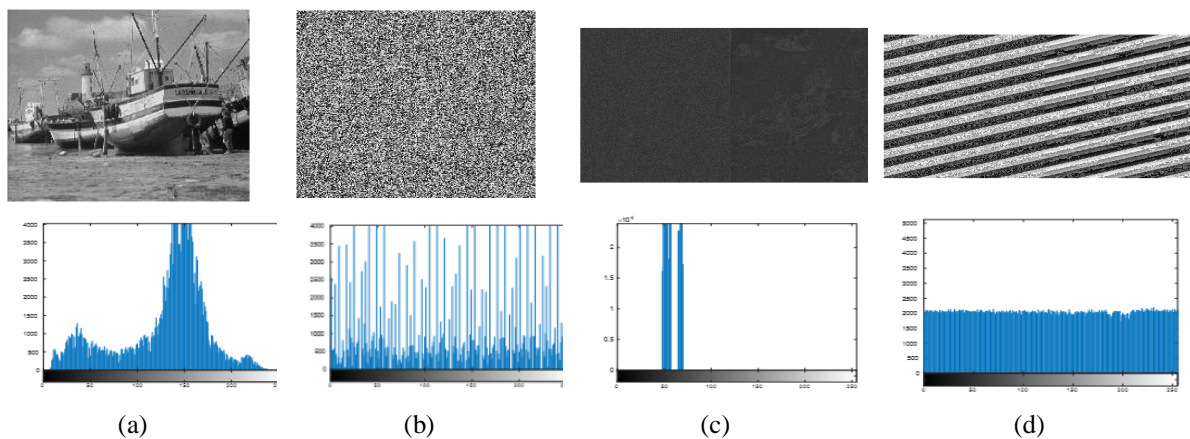


Figure 4. 512×512 Boat image (a) secret image, (b) decomposed image, (c) converted to ASCII code, and (d) ciphered image

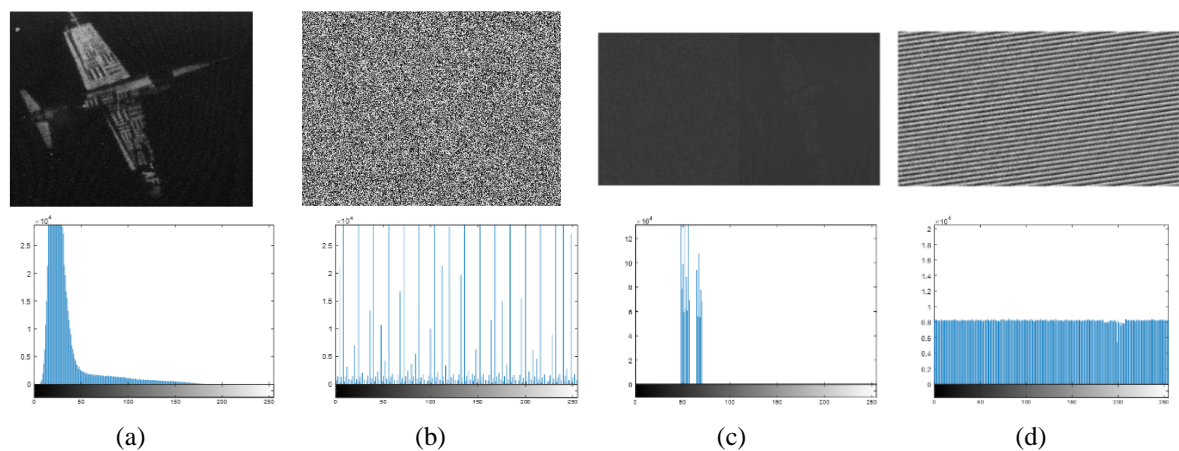


Figure 5. 1024×1024 Airplane image (a) secret image, (b) decomposed image, (c) converted to ASCII code, and (d) ciphered image

Table 1. Exploration of the performance of the suggested algorithm

Details	Entropy	Time spent at the sending side	Time spent at the receiving side
Aerial of Size 256×256	7.9984	2.334467 seconds	0.942702 seconds
Boat of Size 512×512	7.9995	6.370518 seconds	1.793895 seconds
Airplane of Size 1024×1024	7.9994	36.839402 seconds	7.838441 seconds

Table 2. Entropy comparison between proposed work and [26]

Images	Proposed work Entropy	Entropy of Setyono <i>et al.</i> [26]
Bicycle	7.9987	7.9984
City	7.9983	7.9982
Mandrill	7.9982	7.9982
Gold hill	7.9988	7.9983

Table 3. Time execution comparison between proposed work and [26]

Images	Time of reordering bit plans using binary codes	Time of convert pixels from Hex. Value to ASCII code	Time of ciphering the image of ASCII pixel values	Total time for protection the secret image	Time of Setyono <i>et al.</i> [26] for RSA+Vernam
Bicycle	0.778106	0.054770	0.014312	0.847188	1.27736
City	0.767816	0.053364	0.015928	0.837108	1.20308
Mandrill	0.826152	0.041013	0.022173	0.889338	1.38710
Gold hill	0.761701	0.057671	0.015795	0.835167	1.31398

As clearly shown in results of Tables 2 and 3 the entropy and time execution are enhanced in proposed algorithm compared with algorithm in [26]. Six factors used to compare the ciphering algorithm in [26] with proposed method are type of secret image, number of security schemes in algorithm, the inputs required for the image encryption scheme, the inputs required for the image decryption scheme, keys features and the size of the secret image after ciphering. First and final factors are same in two algorithms, while other factors are better in proposed method as in Table 4. As a result, the proposed algorithm is better in most factors from algorithm in [26].

Table 4. Comparison between algorithm in [26] and proposed algorithm

Comparison points	Setyono <i>et al.</i> [26]	Proposed scheme
Type of the secret image	Grayscale image	Grayscale image
Number of security schemes to protect the secret image	Two security schemes: 1. RSA algorithm 2. Vernam cipher	Three security schemes: 1. Decompose the image using binary codes, and then alter the order of bit planes. 2. Convert the image into a hexadecimal system to separate the value of each pixel in the hexadecimal system into two ASCII values. 3. Encrypt the image that contains ASCII pixel values with a secret key matrix that is the same size as the image.
The inputs required for the image encryption scheme	1. Public key of RSA scheme. 2. Vernam key.	Only a secret grayscale image, thus the encryption scheme does not require extra data to be exchanged to retrieve the secret image.
The inputs required for the image decryption scheme	1. Private key of RSA scheme. 2. Vernam key.	Only a cipher grayscale image, where the procedure of creating confidential keys depends on a logical equation derived from the cipher image itself.
Keys features	3. A cipher grayscale image. A random key for Vernam with the strong key of RSA makes it difficult to decrypt the image. However, it requires the exchange of keys between the sender and the receiver, and this requires time and a secure transfer of the secret keys.	The keys are constructed in a flexible way based on the size of a secret image using a logical equation derived from the secret image itself. Therefore, there is no exchange of keys between the sender and receiver parties.
The size of the secret image after ciphering	Twice the size of the original secret image.	Twice the size of the original secret image.

#### 4. CONCLUSION

In this paper, a secure algorithm for encrypting images is suggested. It is capable of providing three levels of security for the images. The first level of security is accomplished by decomposition the image using binary codes, then altering the order of bit planes. After that, bit planes are reconstructed to form the






same size as the image. The second level of security depends on converting the image into a hexadecimal system to separate the value of each pixel in the hexadecimal system into two ASCII values, and then the image is reconfigured to form twice the size of the original image. The third level of security involves encryption image by creating a matrix of secret keys with the same size as the image of ASCII pixel values. The procedure of creating confidential keys depends on a logical equation derived from the secret image itself. The results confirm the efficiency of the suggested algorithm in providing effective protection for confidential images.

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